Virtual modeling of process variation for deep drawing simulations

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Mercedes-Benz

Agenda

- Introduction
  - Product und process validation
  - Deep drawing process
- Product Development Chain
  - Definition
  - Requirements
  - Virtual Methods
- Virtual Modeling
- Example
  - Description
  - Results
- Summary

History of human invention: „Trial and Error“

? !

„Trial and Error“

Reference: Tyrol Museum of Archaeology – www.iceman.it

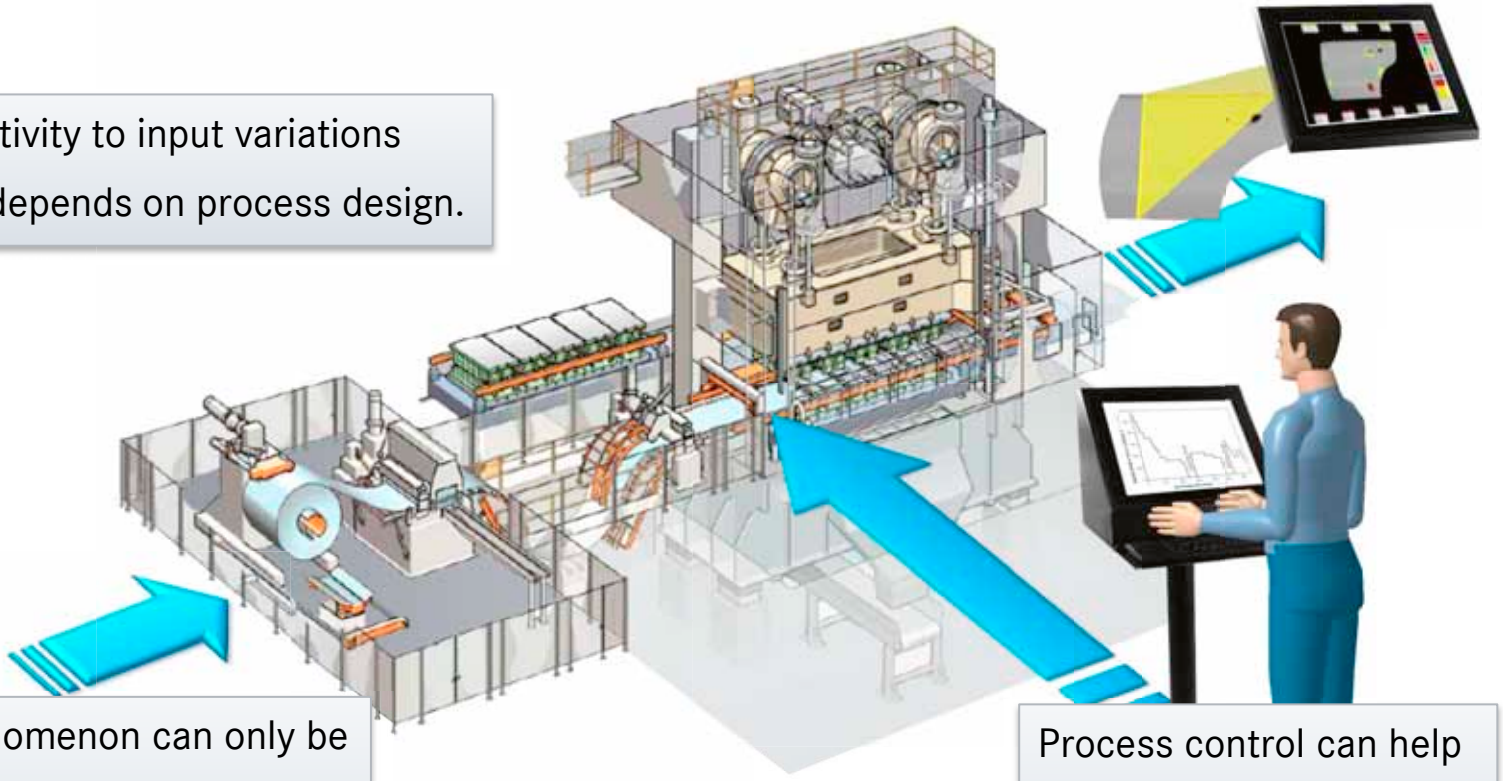
Trial and Error in the automotive industry

Karl-Heinz Baumann, Daimler AG - Fahrzeugsicherheit der Zukunft, Stuttgart 9. Mai 2012

Process variation and control

The results of deep drawing processes underlie variations, even if process control is being kept constant.

The sensitivity to input variations strongly depends on process design.

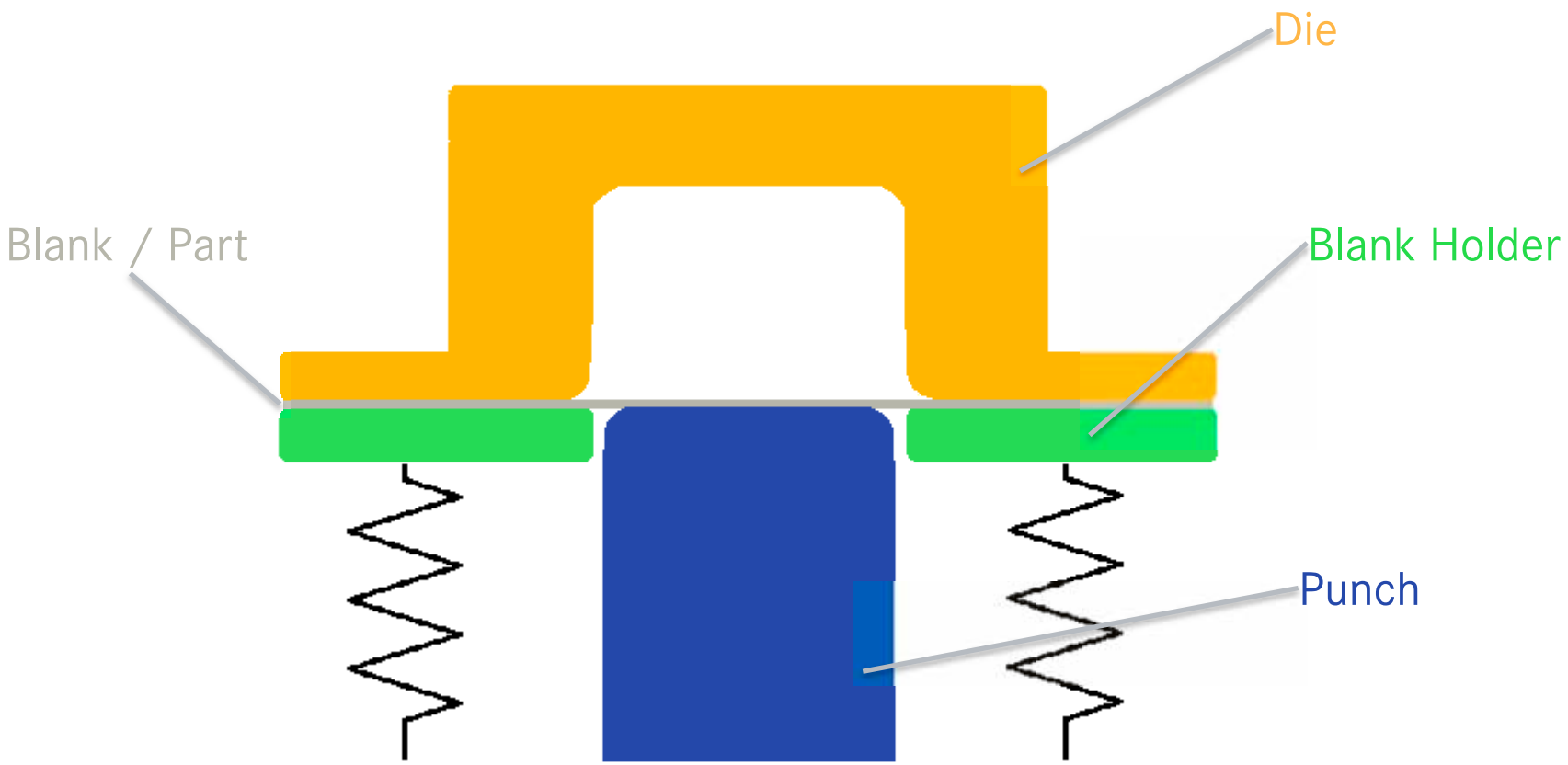


This phenomenon can only be explained by material and process scatter.

Process control can help keeping the process in a state of statistical control.

Deep Drawing Process

Deep drawing is one of the most important method for car body parts production.



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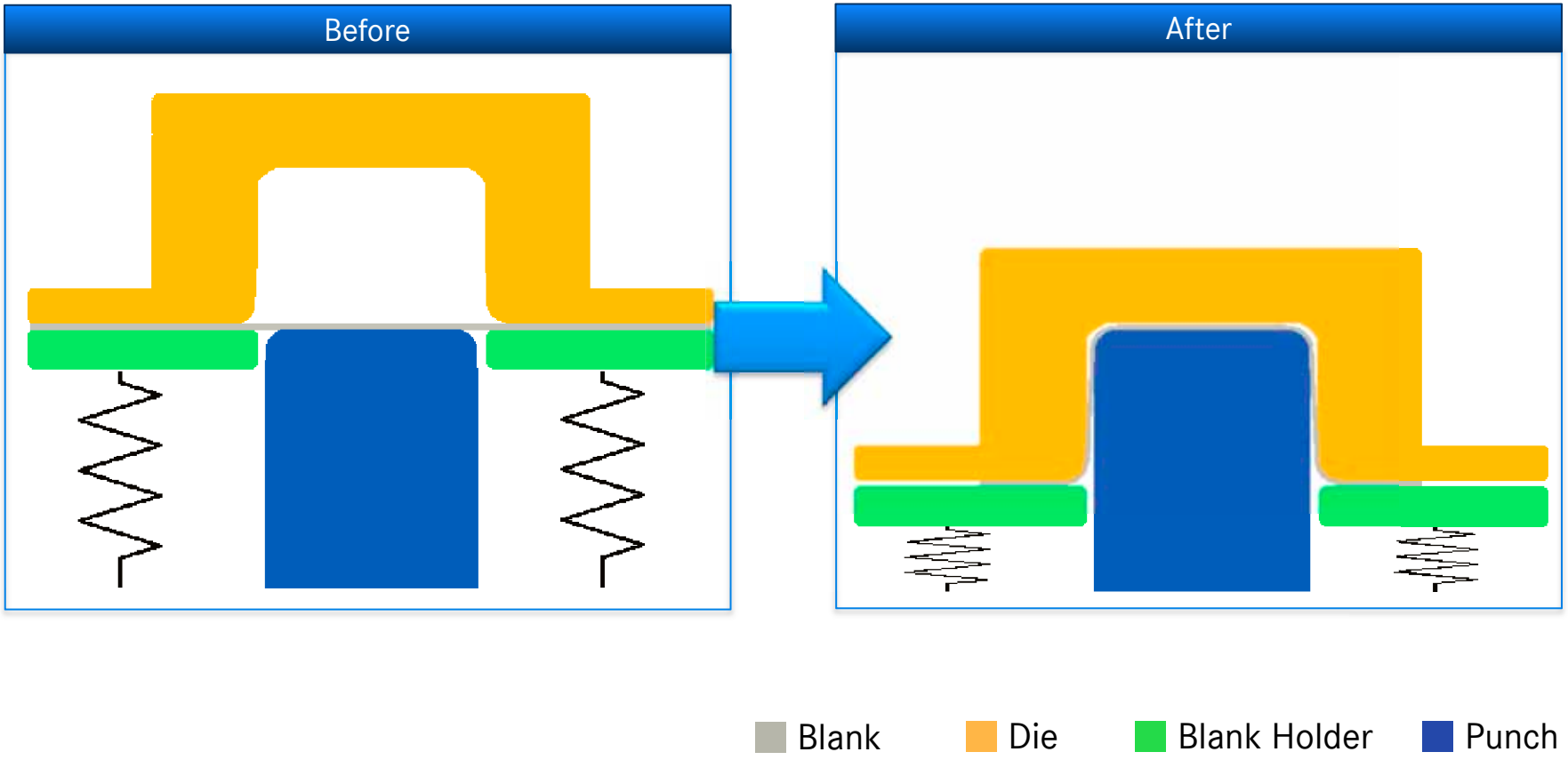
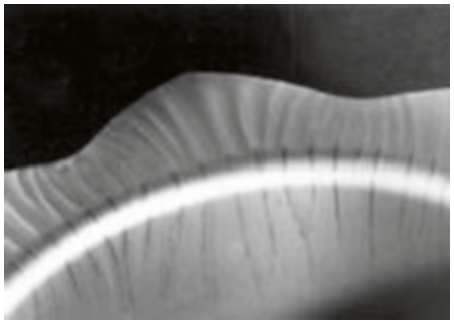


Quality / Failure criteria

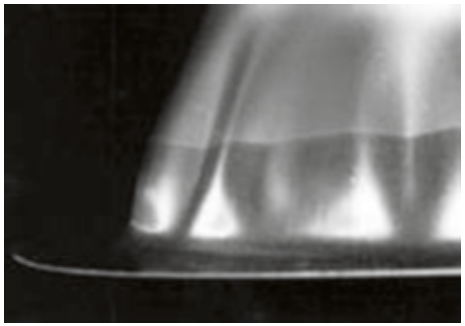
Cracks[1)]

Wrinkles[1)]

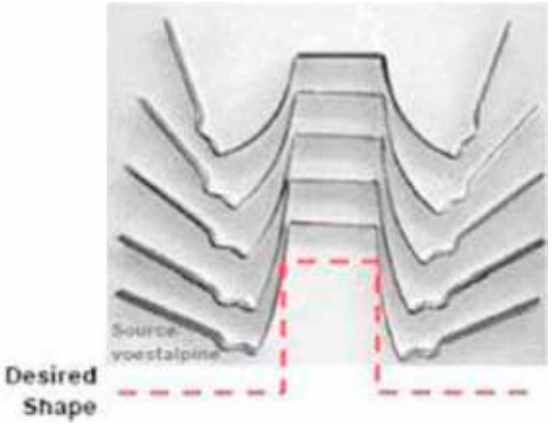
1st type



2nd type

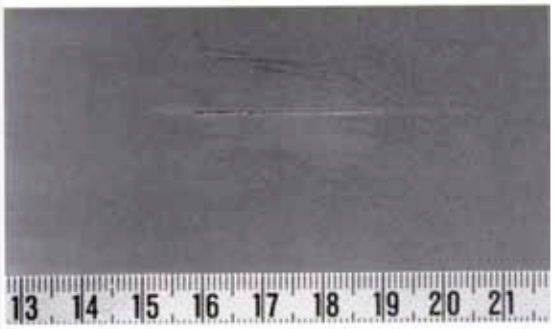


Dimensional Accuracy / Spring Back[2)]

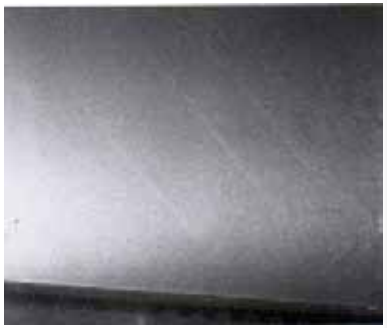


Surface Defects

Scratches

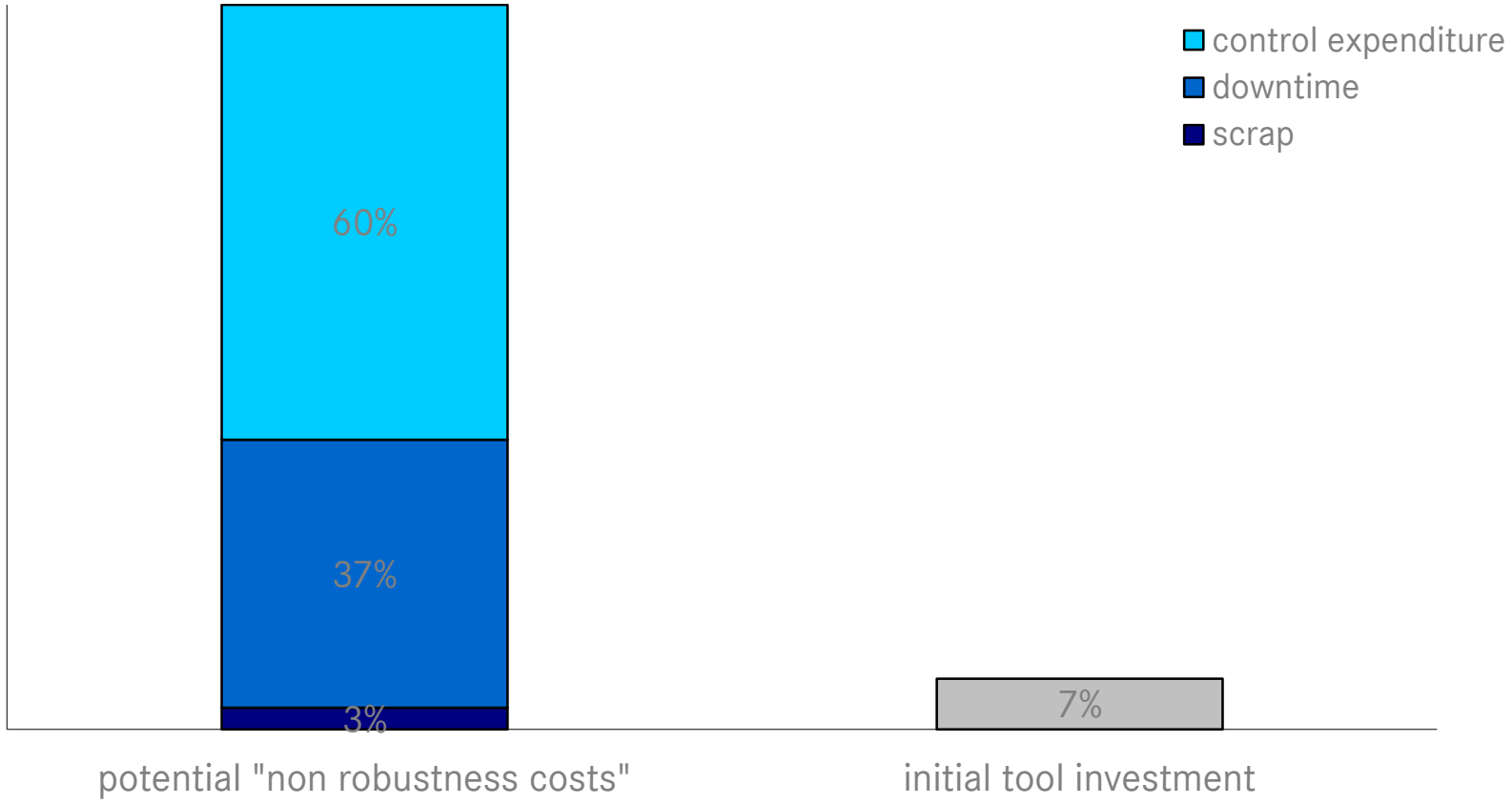


Stretcher strains



1) Doege, Behrens: Handbuch Umformtechnik, Springer Verlag, Heidelberg, 2007; 2) Voestalpine

“Non robustness costs” can exceed initial investment expenditures

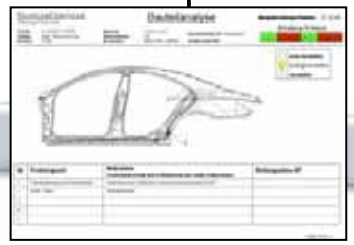


Reference: Grossenbacher, K.: Virtuelle Planung der Prozessrobustheit in der Blechumformung, 2008

Product Development Chain

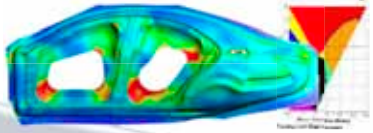
Design

Development



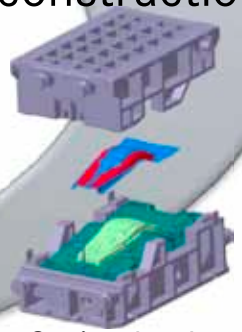
- Feasibility study

Process planning



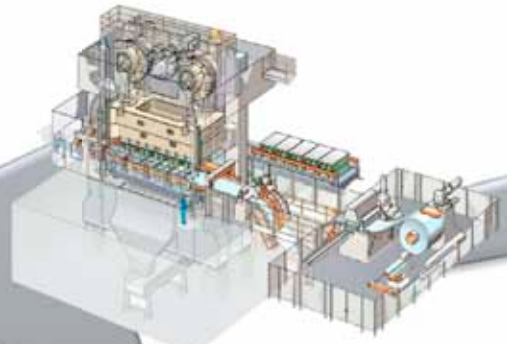
- Cracking
- Wrinkling
- Surface quality
- Spring back

Tool design and construction



- Spring back
- Process robustness
- Tool optimization and compensation
- Try out

Production



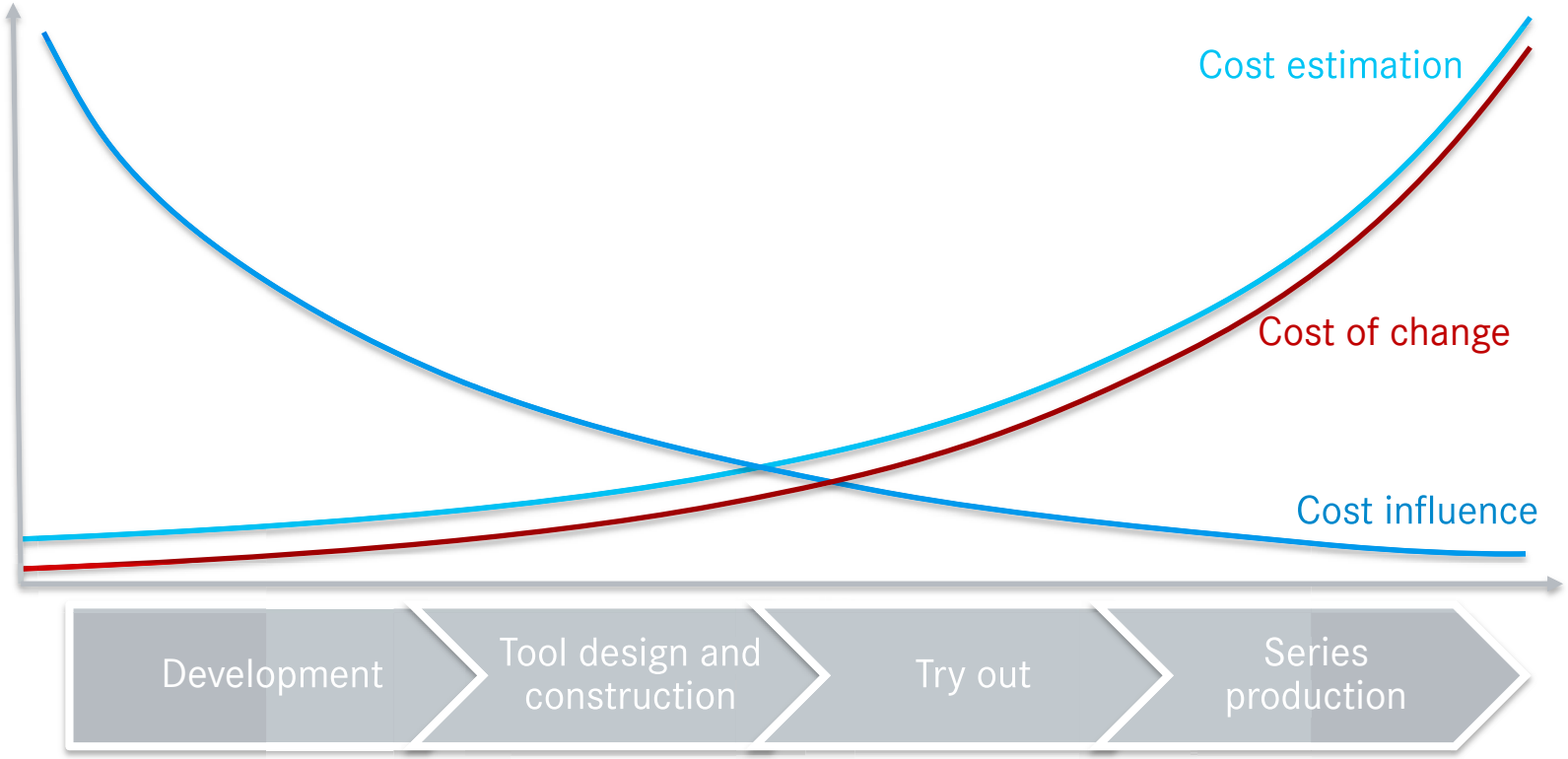
- Process control

Cost influence vs. cost estimation

With increasing product development cycle:

- The possibilities to calculate production costs increase.
- Costs to change manufacturing processes raise rapidly.
- The potential to influence production costs drops.

=> Process robustness should be taken into account in every product development step.

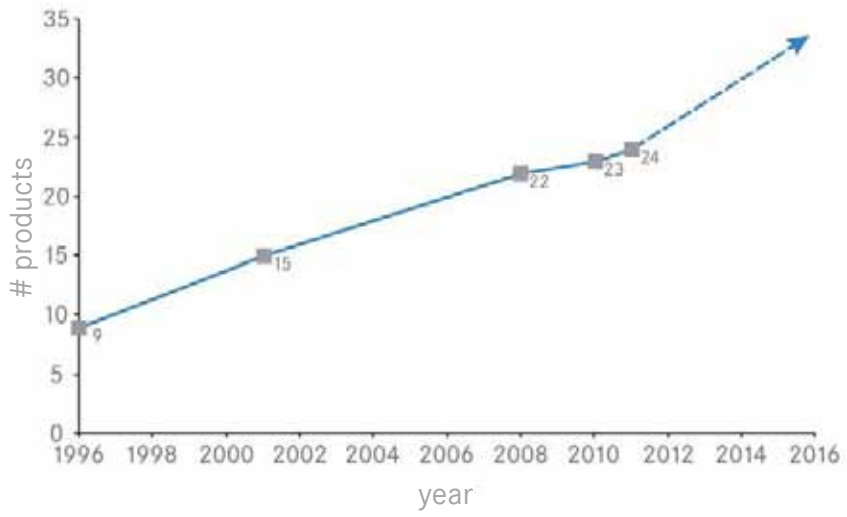


Development cycle time

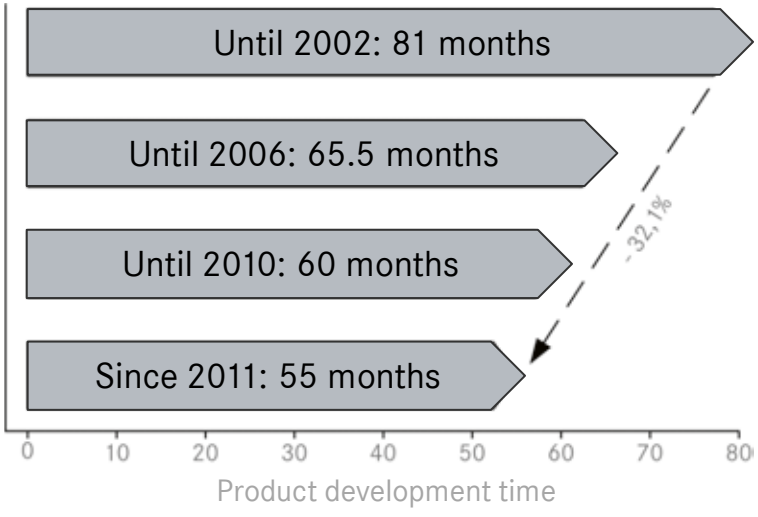
- More products have to be developed in a shorter time.
- Classical methods are too expensive and too time consuming.

=> Virtual methods have to be used.

Number of products Mercedes-Benz Cars (without Smart)



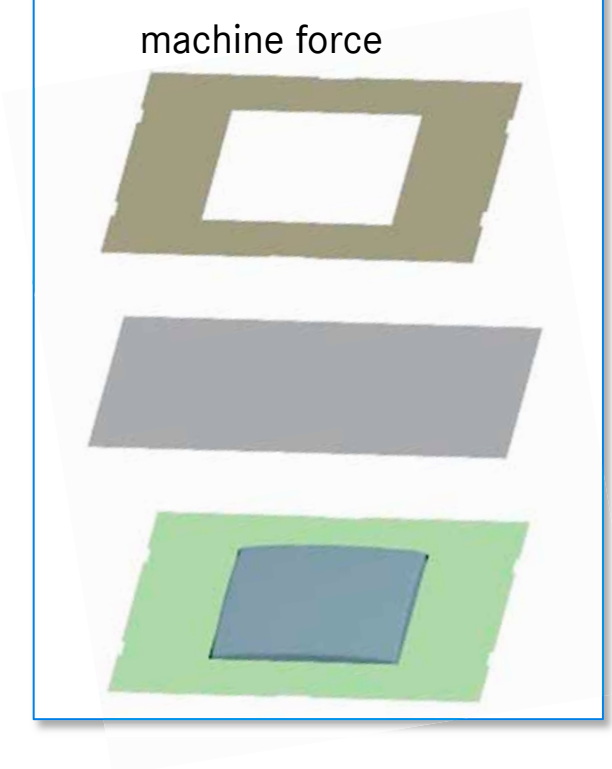
Development Time-to-Market period



Virtual Models: Degree of abstraction

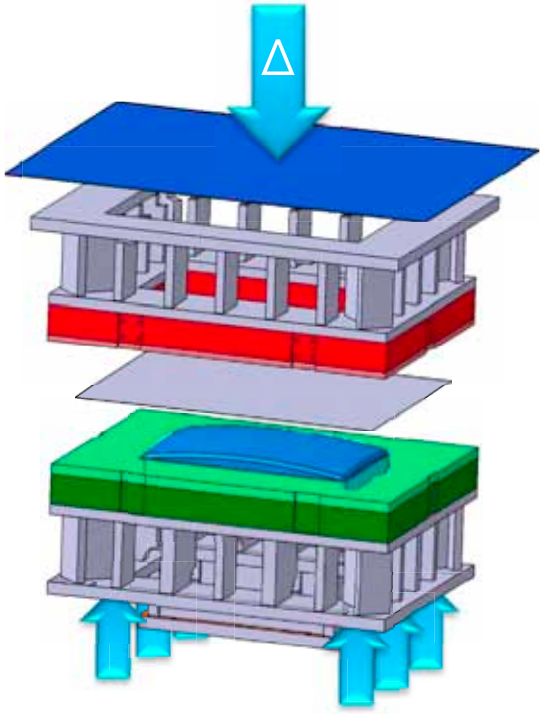
Simple

- Rigid Shells
- No tool or machine elasticity
- Uniform transmission of machine force



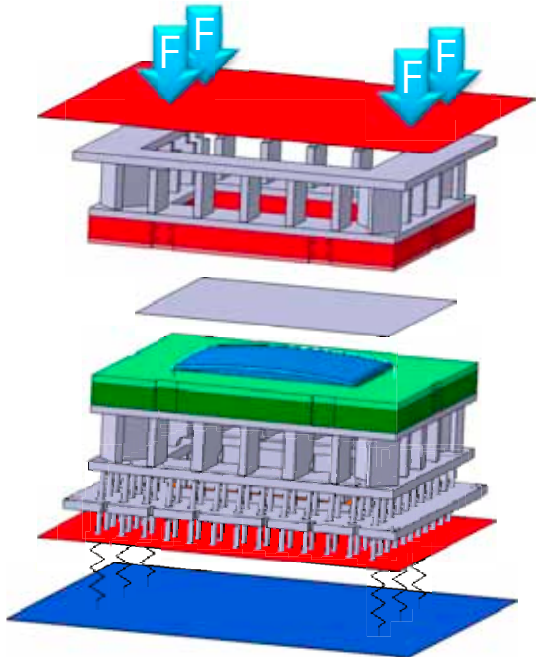
Medium

- Elastic tools using volume elements
- Direct transmission of machine forces

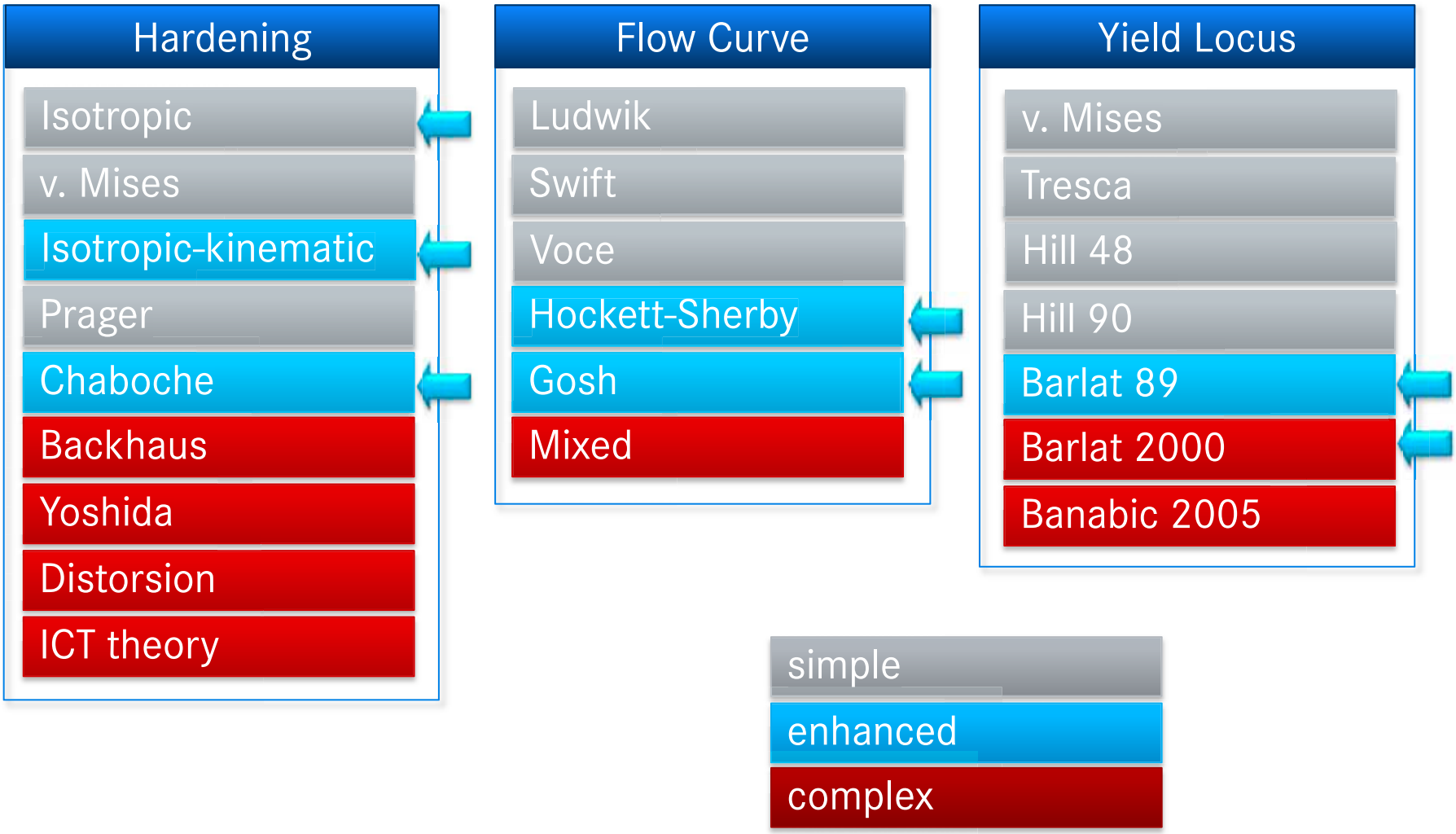


Complex

- Elastic tools using volume elements
- Force transmission and elasticity of machinery using elastic planes



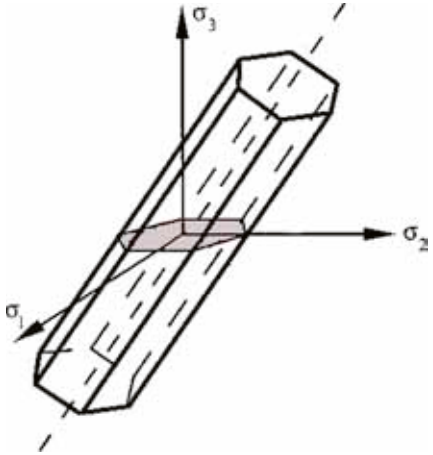
Virtual Models



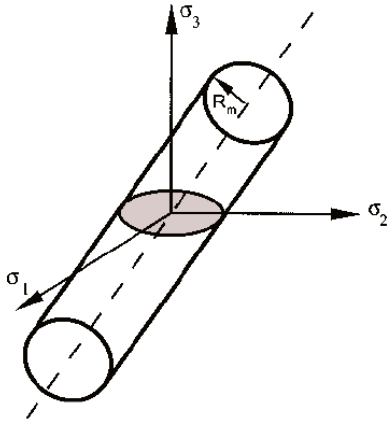
Reference: Roll, K.: State of the Art of Numerical Modeling in Sheet Metal Forming, Erlangen, 2012-03-14

Yield locus description

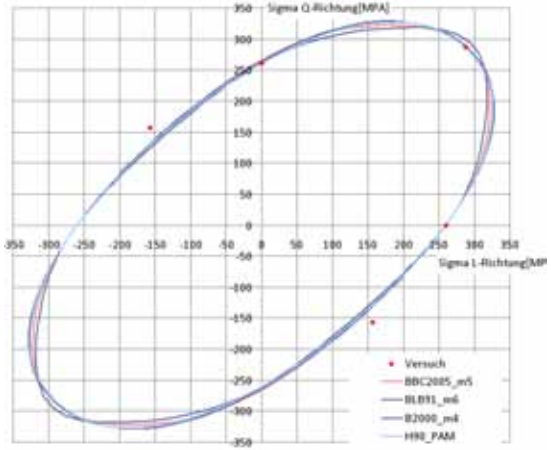
Model	σ_0	σ_{45}	σ_{90}	R_0	r_{45}	r_{90}	σ_b	r_b	Parameters	Free
Hill 48	X	-	-	X	X	X	-	-	4	0
Hill 90	X	-	-	X	X	X	X	-	5	0
Barlat '89	X	-	-	X	X	X	X	-	5	0
Barlat 2000	X	X	X	X	X	X	X	X	8	1
Banabic 2005	X	X	X	X	X	X	X	X	8	1



Tresca



v. Mises



H90, B2000, BL90, BBC2005

Reference: Roll, K.: State of the Art of Numerical Modeling in Sheet Metal Forming, Erlangen, 2012-03-14

Example: Frame Rail E class

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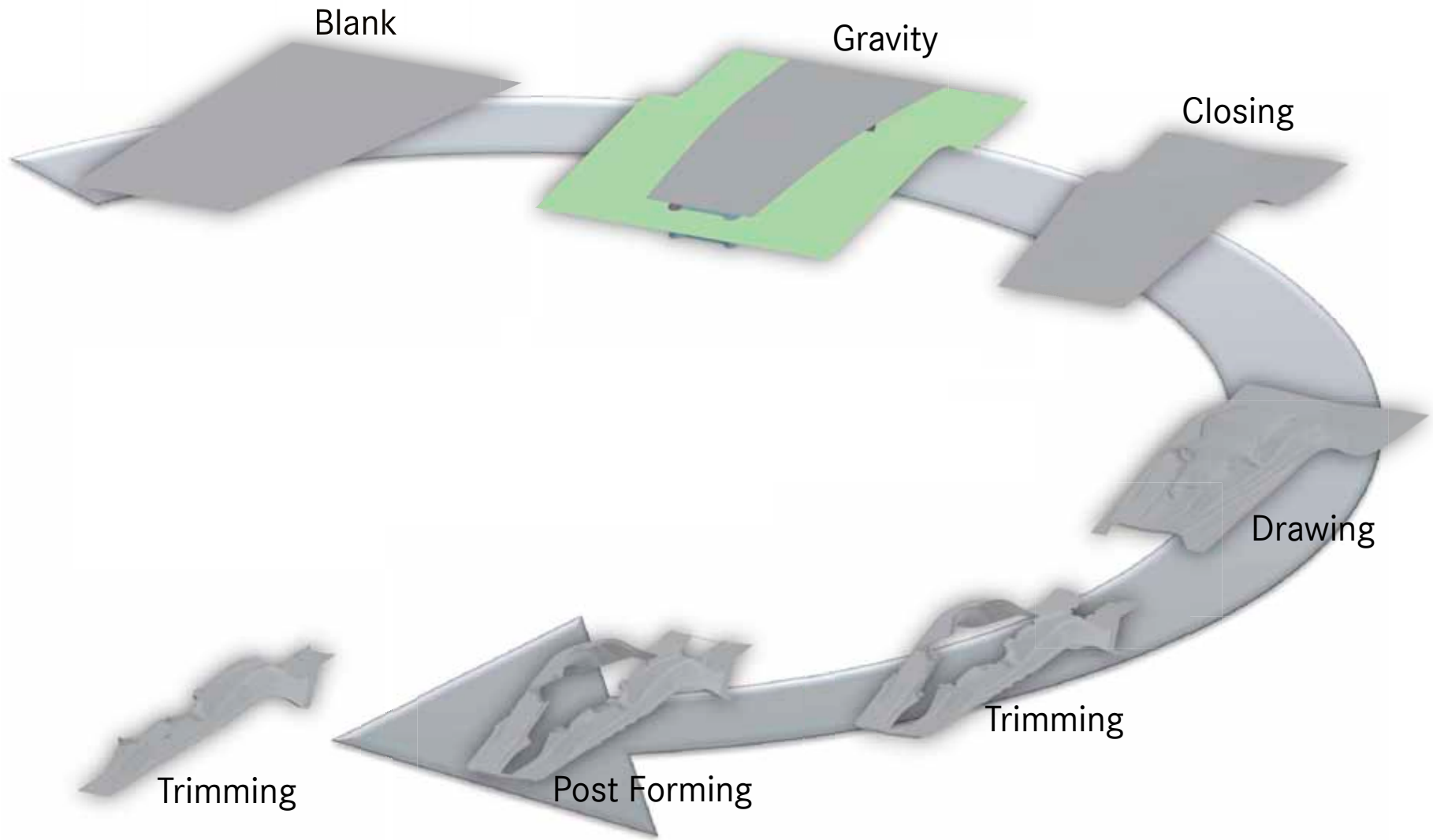


Input parameter: Distribution assumptions

		AF linear correlation				Delivery spec. no correlation				Measured			
		Mean	σ	Min.	Max.	Mean	σ	Min.	Max.	Mean	σ	Min.	Max.
Blank	Thickness [mm]	1.75	0.02	1.69	1.81	←				←			
	X-Position [mm]	0.01	0.33	-1	1								
	Y-Position [mm]	21	0,33	20	22								
	Rotation [mm]	—				—				0.01	0.167	-0.5	0.5
Flow Curve	$R_{p0,2}$ [GPa]	0.382	0.0133	0.344	0.424	0.360	0.0133	0.340	0.420	0.3731	0.01976	Log-Normal	
	Rm	0.449	0.0167	0.388	0.488	0.450	0.0133	0.410	0.490	0.4541	0.01678	Log-Normal	
Anisotropy	R_{00}	0.76	0.05	0.61	0.91	0.627	0.05	0.477	0.777	0.67	0.05	0.52	0.82
	R_{45}	1.21	0.08	0.97	1.45	1.1813	0.08	0.9413	1.4213	1.18	0.08	0.94	1.42
	R_{90}	0.97	0.06	0.78	1.16	0.903	0.06	0.723	1.083	0.98	0.06	0.8	1.16
Process	Friction	0.07	0.0015	0.063	0.077	←				←			
	Blank holder force [kN]	500	16.67	450	550								
Numeric	Yield Curve	Barlat '89				Barlat 2000				Barlat 2000			
	FC Formulation	Gosh				Gosh				Gosh + Cowper-Symonds			
	Element	Belytschko-Lin-Tsay				Fully integrated				Fully integrated			
	# IP	3				5				7			

1

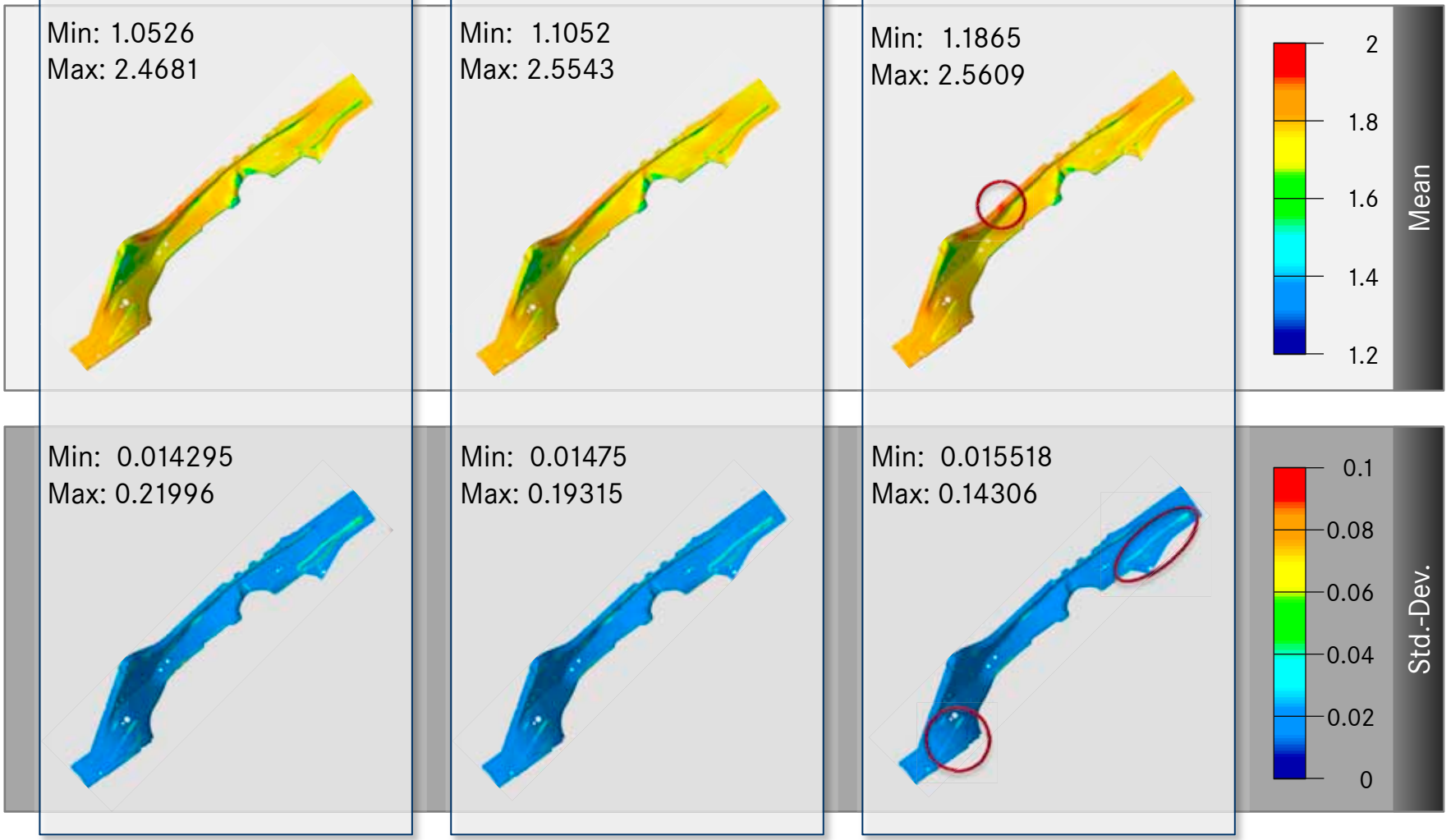
1

1

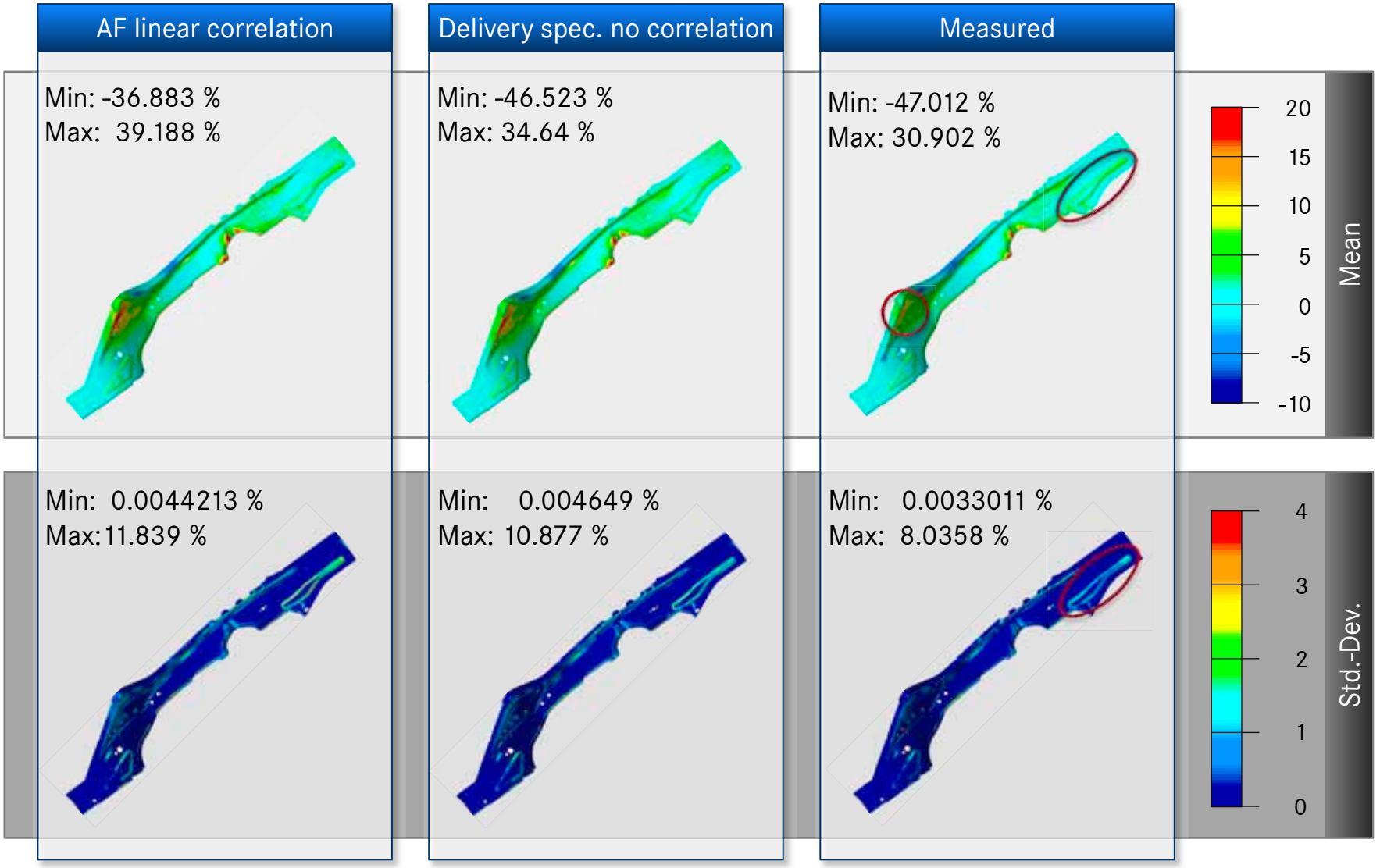
0.64166

Example: Results - Thickness

AF linear correlation	Delivery spec. no correlation	Measured
Min: 1.0526 Max: 2.4681	Min: 1.1052 Max: 2.5543	Min: 1.1865 Max: 2.5609
Min: 0.014295 Max: 0.21996	Min: 0.01475 Max: 0.19315	Min: 0.015518 Max: 0.14306

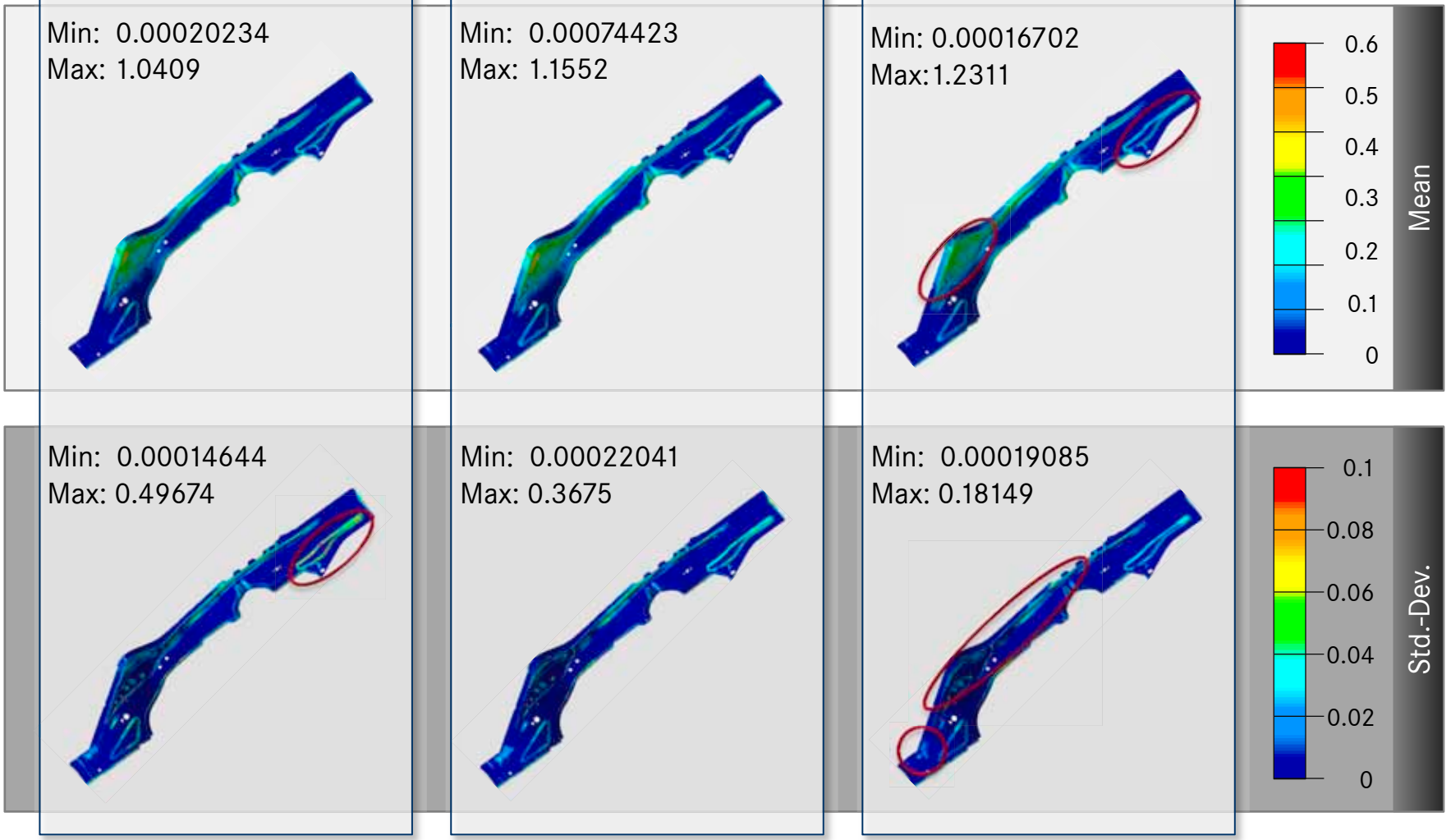


Example: Results - Thinning



Example: Results – Effective Plastic Strain

AF linear correlation	Delivery spec. no correlation	Measured
Min: 0.00020234 Max: 1.0409	Min: 0.00074423 Max: 1.1552	Min: 0.00016702 Max:1.2311
Min: 0.00014644 Max: 0.49674	Min: 0.00022041 Max: 0.3675	Min: 0.00019085 Max: 0.18149



Summary

- Product development is facing increasingly shorter time-to-market cycles.
- Simultaneously, the complexity of production processes steadily increase.

⇒ **This can only be handled by usage of virtual methods.**

- Current mechanical material parameters used in quality control are insufficient to precisely describe material scatter.
- Virtual methods must be improved to incorporate real process and material scatter.
- Knowledge of real input scatter and distribution is evident for robustness analysis of deep drawing processes.

⇒ **Further research is necessary to analyze real material scatter and to incorporate these variations into virtual models.**

Thank you for your attention!

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